FACTORS AFFECTING COYOTE PREDATION OF SHEEP AND LAMBS:

A Statistical Analysis

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16. Abstracts

This paper presents a statistical analysis of the relationships among coyote abundance indices, lamb losses, ranch management practices, and predator control efforts. Regression, discriminant, and cluster analyses were run. Some general tendencies were found, although much of the variation in lamb losses could not be explained.

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Control
Discriminate analysis
Indexes
Inventories
Linear regression
Losses
Management
Management methods
Pest control
Production
Regression analysis
Reliability
Scatter diagrams
Sheep
Statistical analysis
Statistical data
Variability

17b. Identifiers/Open-Ended Terms

Cluster analysis
Coyotes
Fish and Wildlife Service
Lambs
Populations
Predation
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FACTORS AFFECTING COYOTE PREDATION OF SHEEP AND LAMBS: A STATISTICAL ANALYSIS

by Louise M. Arthur 1/

INTRODUCTION

Each year sheep ranchers throughout the western United States attribute a high percentage of their lamb and sheep losses directly to coyote predation. Even with restricted Federal, State, and local control programs, 1974 estimates of herd losses to coyotes averaged 8 percent for lambs and 2.5 percent for sheep (1). 2/ The substantial variance in predation losses among States and producers raises questions regarding the factors underlying reported loss levels. Is there, for instance, any relationship between lamb losses and local coyote populations? Do differences in control programs or ranch management practices explain any of the variation? This paper presents an attempt to answer these questions through a statistical analysis of the relationships among lamb losses, coyote populations, and control efforts.

DATA AND PROCEDURES USED

To measure the relationship of coyote populations and predator control to sheep losses, regression, cluster, and discriminant analyses were applied to a data set containing the combined responses from two surveys of sheep ranchers in 15 western States--Arizona, California,

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1/ Social Science Research Analyst, Natural Resource Economics Division, Economics, Statistics, and Cooperatives Service, Tucson, Arizona. I would like to thank Russell L. Gum, Economics, Statistics, and Cooperatives Service for his assistance throughout the analysis, and W. Robert Wilson, University of Alberta, for his careful editting.

2/ Underscored numbers in parentheses refer to references listed on page 20.

Idaho, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. The first, conducted in January 1975, was a mail survey to 28,000 ranchers representing all sizes and types of sheep operations. Thirty-two percent, 8,910 ranchers, responded with the requested information regarding 1973 and 1974 herd inventories and animal losses by cause. Conducted concurrently was a second survey which consisted of personal interviews with 911 sheep producers with herds of 50 or more sheep in the principal sheep producing areas (fig. 1). This survey included detailed information on management practices as well as herd inventories and livestock losses by cause (1). Only ranchers responding to both surveys were included in the sample used in this analysis, resulting in 888 observations. The Federal trappers on those ranches with control agreements with the Fish and Wildlife Service were then surveyed with the cooperation of the U.S. Fish and Wildlife Service. The combined information from the three surveys--inventories and losses, management practices, and control efforts--resulted in information on 269 variables. To obtain a more succinct set of variables several preliminary regression, discriminant, and cluster analyses were run on the entire set of 269 variables. These analyses revealed that many variables have extremely low relationships to the dependent variable--lamb and sheep losses or to other variables in the set; many of these variables were eliminated from further analyses. Other variables, such as expenditures for individual control methods, were combined into summary indices. The final package included sixty-seven variables (table 1). Only those cases with responses to all 67 variables were used, resulting in a sample of 766 cases from the original 888.

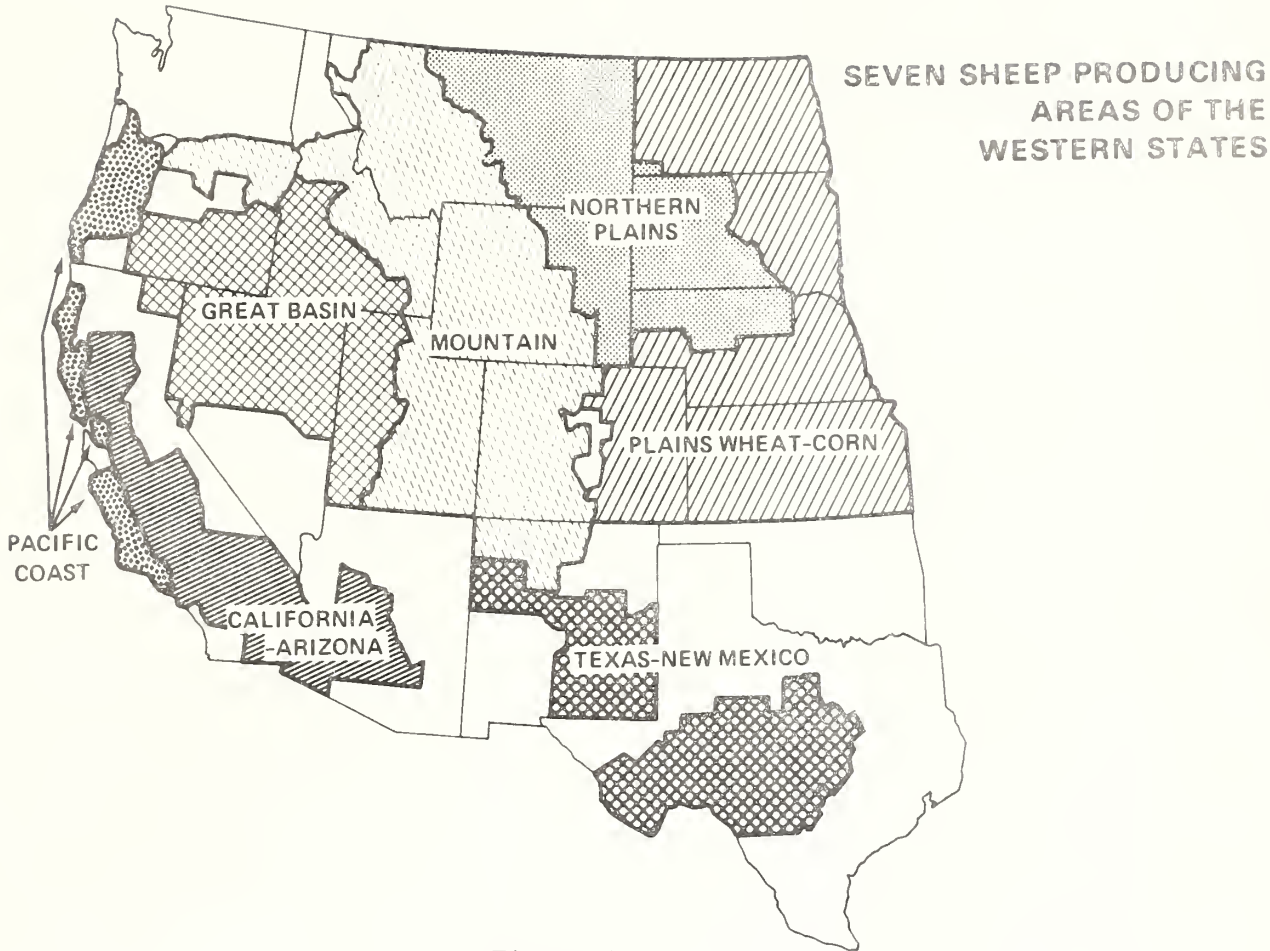

Figure 1.

Plains Wheat Corn: rolling prairies of North Dakota, eastern South Dakota, Nebraska, Kansas, and eastern Colorado.

Northern Plains: dry desert and plains portions of western South Dakota, eastern Wyoming, and eastern Montana.

Texas-New Mexico: Edwards Plateau of Texas and central and southeastern New Mexico.

Mountain: mountainous portions of Montana, Oregon, Idaho, Utah, Wyoming, Colorado, and New Mexico.

Great Basin: primarily the dry desert terrain of southern Oregon, southwestern Idaho, northern Nevada, and western Utah.

California-Arizona: central valleys of California and southwestern Arizona.

Pacific Coast: coastal mountain ranges of California and Oregon.

Table 1.--Mean values and standard deviations for 67 variables describing sheep ranching operations

Variable	Mean	Standard deviation
Mountain area 1/	.3264	.4689
Plains: wheat and corn area 1/	.1384	.3453
Northern Plains 1/	.1619	.3683
Texas/New Mexico 1/	.1214	.3266
California/Arizona	.0849	.2787
Pacific Coast 1/	.1123	.3157
Great Basin 1/	.0548	.2276
Ranches per square mile 2/	.0937	.1049
Sheep per square mile 2/	25.0603	19.3987
Lambs born 1974	68.9204	390.5755
Percentage of lambs born: Jan.	9.6436	20.5898
Feb.	16.5731	28.5215
March	18.4112	30.1141
April	21.1540	34.4705
May	19.3721	35.4718
June	1.5183	7.5896
July	.0274	.4907
Aug.	.0144	.3328
Sept.	.3890	4.4323
Oct.	1.9556	8.7295
Nov.	4.3525	13.9722
Dec.	5.2467	15.0100
Lambs docked 1973	1005.1488	1667.1330
Lambs docked 1974	982.0000	1593.0034
Number of sheep, Jan. 1. 1974	1041.3499	1745.3155
Percentage shed-lambed 3/	56.5483	47.8206
Miles of coyote fence	2.3316	16.4775
Percentage of ewes fenced before marketing	75.0757	41.8716
Percentage of ewes fenced after marketing	74.3668	43.0015
Percentage trailed only 3/	16.0718	35.8955
Miles trailed 1973	15.3825	76.3156
Number of herders per sheep	.0003	.0008
Percentage Bureau of Land Management grazed 3/	7.4687	16.6057
Percentage Forest Service grazed 3/	2.8159	8.7075
Percentage State grazed 3/	1.6501	8.8073
Percentage private range 3/	42.8894	34.3189
Percentage grain pasture and crop residue	36.5718	33.8754

Continued

Table 1.--Mean values and standard deviations for 67 variables describing sheep ranching operations (continued)

Variable	Mean	Standard deviation
Coyote population index 1972	76.1619	46.3305
Coyote Population index 1973	86.1371	50.1958
Coyote population index 1974	78.9008	54.8498
Coyotes per sheep 1972	.0044	.0102
Coyotes per sheep 1973	.0046	.0099
Coyotes per sheep 1974	.0046	.0133
Lambs lost before docking, all causes	86.8290	181.1862
Lambs lost to coyotes before docking	23.0822	82.9748
Lambs lost after docking, all causes	80.5235	149.3083
Lambs lost to coyotes after docking	44.5955	94.8352
Sheep lost, all causes	73.4517	187.8556
Sheep lost to coyotes	18.2180	52.5219
Lambs lost to coyotes 1973	66.7833	168.9424
Proportion of lambs lost 1973 4/	.0872	.1384
Proportion of lambs lost 1974 4/	.0935	.1847
Sheep lost to coyotes 1973	23.1149	72.0636
Any control expenses 1/	.4021	.4903
Any tax for control 1/	.4896	.4909
Control expenditures (dollars)	97.4517	247.7648
Any Federal control 1/	.2911	.4543
Coyotes taken, corrective Federal	2.5248	16.3193
Coyotes taken, preventive Federal	1.7311	8.6371
Expenditures, individual control efforts (dollars)	290.2415	4454.6922
Coyotes taken, individual efforts	4.7937	16.4880
Dollars organizational assessment	25.0222	129.2458
Group control expenses per lamb	519.6736	6446.7941
Coyotes taken, group methods	15.3603	159.4979
Control expenses per coyotes killed 5/	7.3878	89.5527
Control expenses per coyote 5/	17.0656	243.2429
Coyotes killed per lamb	.0061	.0478

1/ No=0, yes=1.
2/ Calculated on county basis.
3/ Breeding herd.
4/ Of lambs docked.
5/ Figured from group expenditures for predator control.

Cluster Analysis

Because linear regression analysis revealed no evidence of any significant linear trends, a more general statistical procedure, cluster analysis (3), was employed. Unlike regression analysis, cluster analysis does not require identification of a dependent variable. Instead, it reveals general covariation trends among variables in a data set by clustering, or grouping, mathematically related variables.

Nine clusters of variables were identified in the original set of 67 variables (table 2). Some of the clusters have low statistical reliabilities (table 2)-- particularly clusters 6 and 9--indicating that the relationships are not strong. Many variables were not even included in clusters because they showed so little common variation with other variables in the set.

Following the clustering of mathematically related variables, cluster scores were calculated for each of the 766 sheep-ranching operations. To calculate a cluster score, each operator's responses to each of the variables in the cluster were standardized to a common mean and standard deviation, and then summed. For example, to determine a respondent's score on cluster 1--size of operation-- standardized values of that operator's response to the definers of that cluster-- lambs docked or marketed, and number of sheep on Jan. 1, 1974--were added. This procedure was repeated for all dimensions and all operators.

In the next step of cluster analysis groups of observations with similar cluster scores were identified (table 3). These groups were labeled "otypes" and defined as sheep raising operations having homogeneous characteristics. To develop the otypes, cluster scores were computed for each sheep producer in each cluster. Sheep producers with similar cluster scores on all 9 clusters were grouped into an otype. (All operations were not included in an otype. Some were unique; they are shown in table 3 as unclassified. The similarity of respondents in an otype was measured by the overall homogeneity coefficient (column 10, table 3). The resulting high homogeneity coefficients indicate that otypes are comprised of operators with very similar characteristics on

Table 2.--Structural dimensions and their reliabilities, developed from 67 variable sample

Dimension	Defining variables	Reliability Coefficient
1. Operation size	Lambs born 1974 Number of sheep, Jan. 1, 1974	0.9905
2. Number of coyotes per sheep	Coyotes per sheep 1974 Coyotes per sheep 1973 Coyotes per sheep 1972	0.9731
3. Control expenditures	Control expenses per lamb Control expenses per coyote killed	0.9853
4. Coyotes killed	Coyotes killed per lamb Sum of coyotes killed by all methods	0.9404
5. Coyote population index	Coyote index 1974 Coyote index 1973 Coyote index 1972	0.8968
6. Ranch and sheep density	Ranches per square mile Sheep per square mile	0.5438
7. Use of public land	Percentage of ewes fenced before marketing Percentage of ewes fenced after marketing Number of herders per sheep Percentage Forest Service grazed Percentage Bureau of Land Management grazed	0.8241
8. Number of coyotes taken by Federal trappers	Coyotes taken, Federal corrective Coyotes taken, Federal preventive	0.7869
9. Shed-lambing	Percentage shed-lambed	0.3399

Table 3.--Mean cluster scores for each group of sheep producers (otypes)

Sheep producing operations (otypes)	Variable Clusters: Operation size 1	Coyotes per sheep 2	Control expendi-tures 3	Coyotes killed 4	Coyote population index 5	Ranch and sheep density 6	Use of public land 7	Coyotes taken by Federal trapper 8	Shed lambing 9	Overall homogen-iety	Number in type	Percentage in type
1. Small-medium, private	47	47	49	49	45	48	46	48	38	0.9354	116	15
2. Small, private	45	48	49	49	42	49	45	48	59	0.9582	200	26
3. Medium-large, public	56	48	51	52	47	48	71	49	39	0.8995	34	4
4. Medium, public	51	48	51	51	47	50	66	50	59	0.8903	56	7
5. Small, high density private	47	47	49	49	53	74	45	48	39	0.9285	55	7
6. Medium, high coyotes	49	52	49	49	66	45	47	49	39	0.8586	55	7
7. Small, low density, private, high coyotes	45	54	49	49	56	42	45	49	59	0.9302	107	14
8. Small, high density, private, high coyotes	46	49	49	49	59	68	44	48	58	0.9327	41	5
9. Large, private	68	47	49	49	49	51	48	49	40	0.8596	23	3
10. Largest, public	72	47	49	49	55	47	66	50	39	0.8950	32	6
Unclassified	-	-	-	-	-	-	-	-	-	-	45	6
Total											766	100

all clusters.

Cluster scores for each otype reveal the characteristics of the operators within that otype. Because cluster scores are restandardized to a mean of 50 and a standard deviation of 10, any otype having a cluster score greater than 50 lies greater than the mean of the entire sample in terms of the characteristic defined by that cluster. For example, otype 10 has a score of 72 on cluster 1, operation size. This otype, then, represents operations which are 2.2 standard deviations above the mean operation size. These comprise the largest operations in the sample.

Some clusters show little differentiation among otypes. Clusters 3 and 4, for example, tend to show mean values for all otypes, suggesting there are no striking differences in control expenditures and coyote kills among these operators when grouped in this manner. The clusters that do differentiate reveal that these 10 groups of operators can be defined only in terms of a combination of operation and coyote population factors. Relatively small operations on private lands 3/ lie in areas of both low (otype 7) and high (otypes 5 and 8) ranch densities, and may either shed-lamb (otypes 2, 4, 7, and 8) or range-lamb (otypes 1, 5, and 10). Operations closer to the mean in size and using public lands also include both shed-lambing (otype 4) and range-lambing operations(otypes 3 and 10). Almost any combination of variables can be found, except that large operations are usually in areas of lower ranch densities and tend to range-lamb, and smaller operators tend to use primarily private pasture. These factors are further clarified and detailed in table 4, which provides the unstandardized mean values for each otype on several dimensions. The 45 operations listed as unclassified do not fit any of the 10 defined

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3/ None of these operations fall beyond 0 .4 standard deviations below the mean on the size dimension and 0.6 standard deviations below the mean on the public land use dimension. However, the number of cases that are included in these otypes indicates that small, private operations predominate in this sample, weighting the mean (50) toward smaller producers who use private lands.

Table 4.--Unstandardized mean values for each otype, 1974.

Variable	Otype 1	2	3	4	5	6	7	8	9	10
Percentage lamb losses, 1974	9.5	5.1	15.1	9.8	11.2	22.7	9.0	4.0	7.0	7.0
Number of lambs docked	565	295	1934	1310	411	790	284	345	3797	4529
Number of coyotes taken, private effort	1.9	1.0	14.4	6.6	.7	7.8	1.6	.1	4.4	25.7
Predominant producing area*	3	2	1	1	4	4	1	5	4	6
Sheep per square mile	25	22	19	26	65	19	10	42	39	29
Ranches per square mile	.07	.09	.10	.09	.28	.05	.05	.31	.05	.03
Percentage using public land	8.2	3.7	50.6	36.8	1.3	5.9	4.0	0.0	11.0	34.7
Percentage shed-lambing	3.2	98.3	4.5	98.2	3.5	5.9	98.0	96.6	9.4	4.1
Percentage trailing breeding herd	18.7	12.8	52.9	36.7	2.7	4.0	6.5	6.3	15.2	25.0
Percentage using Federal trappers	26.2	20.5	65.7	51.8	10.9	32.7	29.0	2.4	39.1	28.1
Coyote population index	58	38	51	50	99	165	121	123	77	82

*1. Mountain area. 2. Wheat-Corn Plains. 3. Northern Plains. 4. Texas/New Mexico. 5. Pacific Coast. 6. California/Arizona.

otypes. An example might be a small operator who uses public lands or a large operator who shed-lambs.

Discriminant Function Analysis

Cluster analysis revealed some general types of operational conditions that characterized the sample sheep operations. The question concerning the relationship of these conditions to sheep and lamb losses, however, could not be answered by cluster analysis alone. Because of the interactions and nonlinear relationships among variables characterizing each operation type, regression analyses were unsuccessful in describing relationships between livestock losses and specific ranching conditions such as ranching practices, environmental characteristics, and coyote populations. Thus, discriminant function analysis (2) was used. Discriminant function analysis relates independent to dependent variables with an objective of distinguishing among groups of cases, in this analysis groups of operators. These groups then become the dependent variable. In this analysis operators were grouped in terms of their losses of marketable lambs to coyotes in 1974, 4/. Each operator was placed into one of three percentage categories: (1) no losses, (2) losses up to 10 percent, and (3) losses over 10 percent. Percentages of each otype population falling into each loss category are presented in table 5. The interactions in this table suggest that otype alone does not effectively predict loss level. Consequently, a discriminant analysis was performed for each otype.

The independent variables used in the discriminant analyses included those variables in table 1 which do not describe the dependent variable, lamb and sheep losses to coyotes. The objective of thisdiscriminant analysis is to select, weigh, and linearly combine these independent variables in such a way that the cases (ranchers) in each loss category (dependent variables) are forced to be as statistically distinct as

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4/ If an operator is to maintain a breeding herd of a given size, he must replace lost sheep with marketable lambs, thereby decreasing his marketable stock by both the numbers of lambs and sheep lost.

Table 5.--Percentage of each otype population in each lamb loss category.

Otype	Percentage lamb loss category		
	<5	5-10	>10
	Percentage of operations		
1	39.0	27.1	33.9
2	52.5	24.5	23.0
3	0.0	35.3	64.7
4	1.8	60.7	37.5
5	63.6	16.4	20.0
6	23.6	34.5	41.8
7	26.2	45.8	28.0
8	70.7	19.5	9.8
9	13.0	65.2	21.7
10	0.0	81.3	18.8
Unclassified	13.3	46.7	40.0
Total	34.7	35.8	29.3

possible (2). The weighted coefficients produced are similar to those generated in multiple regression analyses. These coefficients identify variables which contribute the most to differentiation among loss categories. For example, the analysis of operators in otype 4 reveals that only three variables are needed to maximize discrimination among loss categories 5/: (1) group expenditures for predator control, (2) coyotes taken by preventive Federal programs, and (3) percentages of ewes in fenced pasture between lamb docking and marketing.

The absolute magnitudes of the function coefficients serve as indicators of the relative contributions of associated variables to each function. In this example, "coyotes taken" is the most important for function 1, and "ewes in fence" for function 2. The functions in table 6 have been named to reflect their predominating variables.

The mean scores of each function for each loss category can be plotted in two dimensional space by using these functions as axes, as illustrated for otype 3 in figure 2. These plots can be used to determine the contribution of each variable toward assigning a case to a loss category. The expenditure variable for otype 4 has a coefficient of 0.65 on function 1 and .00 on function 2. These discriminant coefficients define vector a, illustrated relative to the group means (represented as the stars labelled 1, 2, and 3) in figure 2. Increasing the values of this expenditure variable moves the cases in the direction indicated by the vector. Note that vector a proceeds directly toward the centroid of group 3, the category representing the largest losses. Thus, operators in otype 4 with relatively high-control expenses also tend to have high losses, >10 percent. The vector for "ewes in fence" (vector b), on the other hand, tends toward group 1, indicating ranchers with no losses fence relatively large proportions of their breeding ewes. Finally, vector c, representing coyotes taken by Federal preventive action, also points toward group 3; operators within this otype who use Federal control are those with high losses. Table 7 presents loss levels predicted by function coefficients for each otype.

As a check for the adequacy of the discriminant functions, the

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5/ The minimum F level for variable inclusion was 1.5.

Table 6.--Function descriptors and classification reliabilities for each otype

Otype	Otype descriptor	Function 1	Function 2	Percentage correctly identified
1	Medium-small, private	Number of coyotes	Number of lambs	66
2	Small, private	Number of lambs	Number of coyotes taken	64
3	Medium-large, public	Federal program use	--	91
4	Medium, public	Coyotes taken, Federal preventive control	Percentage ewes in fence	68
5	Small, dense, private	Number of coyotes	Federal program use	80
6	Medium, high coyotes	Coyotes taken	Control expenditures	78
7	Small, low density, private	Control expenditures	Federal program use	64
8	Small, dense, high coyotes	Coyote and lamb populations	Coyote population	71
9	Large, private	Private land use	Taxes	100
10	Large, public	Number of coyotes	--	100
	Unclassified	Numbers of sheep and coyotes	Sheep density	76

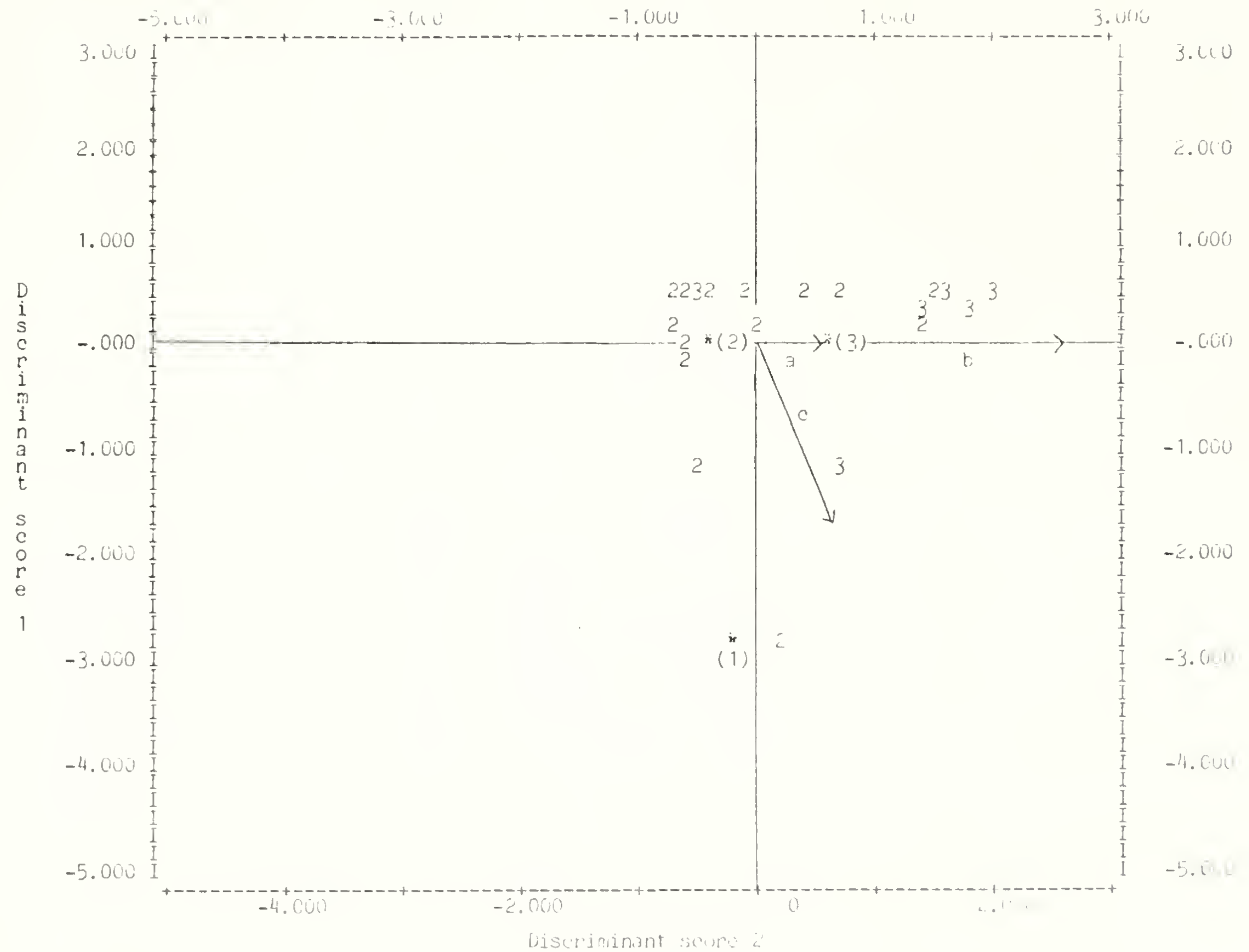

Figure 2.--Plot of discriminant scores and group centroids (*): Study 4.

Table 7.--Predicted percentage losses for each function variable and otype

Variable	Otype 1	2	3	4	5	6	7	8	9	10	Un-classi-fied
Number of lambs 1974	<10	<10	>10	–	–	<10	–	*	0	<10	–
Losses other than to coyotes	>10	*	–	–	–	–	–	–	–	–	–
Any control tax	–	*	>10	–	–	–	–	–	<10	>10	>10
Dollars control tax	>10	*	–	–	–	–	–	–	>10	–	–
Dollars organizational assessment	–	–	–	–	–	–	>10	–	–	–	–
Any control expenses	0	0	<10	>10	–	–	0	–	–	*	0
Group control expenses	–	–	–	–	–	–	–	–	–	<10	–
Coyotes taken, group efforts	–	–	<10	–	>10	–	–	–	>10	–	–
Individual control expenses	–	<10	–	–	–	0	–	–	–	–	–
Coyotes taken, individual efforts	>10	*	–	–	>10	>10	–	–	–	–	–
Miles coyote fence	–	<10	–	–	–	0	–	–	–	–	>10
Use of public land	–	–	–	–	–	–	–	–	<10	–	–
Use of private land	–	–	–	–	–	–	–	–	<10	–	–
Percentage shed-lambed	–	–	–	–	<10	–	*	–	>10	–	–
Percentage ewes fenced	*	–	–	0		–	–	–	–	*	–
Percentage trailed only	–	–	>10	–	–	–	<10	–	–	–	–
Percentage not trailed	–	<10	–	–	>10	–	>10	0	–	–	0
Miles trailed	–	–	<10	–	–	–	–	<10	–	–	–
Herders per sheep	>10	0	>10	–	–	0	–		>10	*	–
Coyote index 1972	0	–	–	–	0	–	>10	0	–	–	–
Coyote index 1973	>10	–	–	–	–	<10	<10	–	–	<10	–
Coyote index 1974	–	–	–	–	–	*	–	>10	–	–	–
Lambs docked 1973	–	–	–	–	–	–	–	–	–	–	–
Federal program use	–	<10	>10	–	<10	<10	<10	<10	–	–	–
Coyotes taken, corrective efforts	–	>10	<10	–	–	–	–	–	–	>10	–
Coyotes taken, preventive efforts	–	0	–	>10	–	–	–	–	–	–	–
Ranches per square mile	–	<10	<10	–	–	–	0	–	<10	–	–
Sheep per square mile	–	–	–	–	–	0	–	0	–	>10	<10
Coyotes per sheep	>10	–	–	–	>10	–	–	–	–	–	*
Expenditures per coyote killed	–	–	–	–	–	>10	>10	<10	–	–	<10

*Group classification tendency cannot be determined from function coefficients for this variable alone.

functions can be used to assign the original set of cases to a loss category. The difference between these assignments and the real losses of the ranchers provides a measure of model precision. Table 6 gives percentages of ranchers correctly classified for each otype, using respective discriminant functions. Examination of positions of individual cases relative to the centroids, as illustrated for otype 4 in figure 3, reveals why the classification routine correctly classifies less than 100 percent of the cases. There is considerable overlap among loss categories in many otypes, even when discriminations are statistically significant.

CONCLUDING OBSERVATIONS

Even with the use of the general statistical tools of cluster and discriminant analyses much of the variation in losses could not be explained by control levels or by the other factors examined. Nevertheless some general tendencies were noted:

1. Small sheep-ranching operations more frequently had either zero or high rates of predation than large operations.

2. Shed-lambing and private land use were associated with low to medium predation rates, while range-lambing and public land use were associated with medium to high rates.

3. High 1973 and 1974 coyote population indices tended to be related to high predation rates in those years.

4. Ranchers using Federal cooperative predator control programs had predation levels of less than 10 percent more frequently than other ranchers.

Although not dramatic, these relationships seem to suggest that

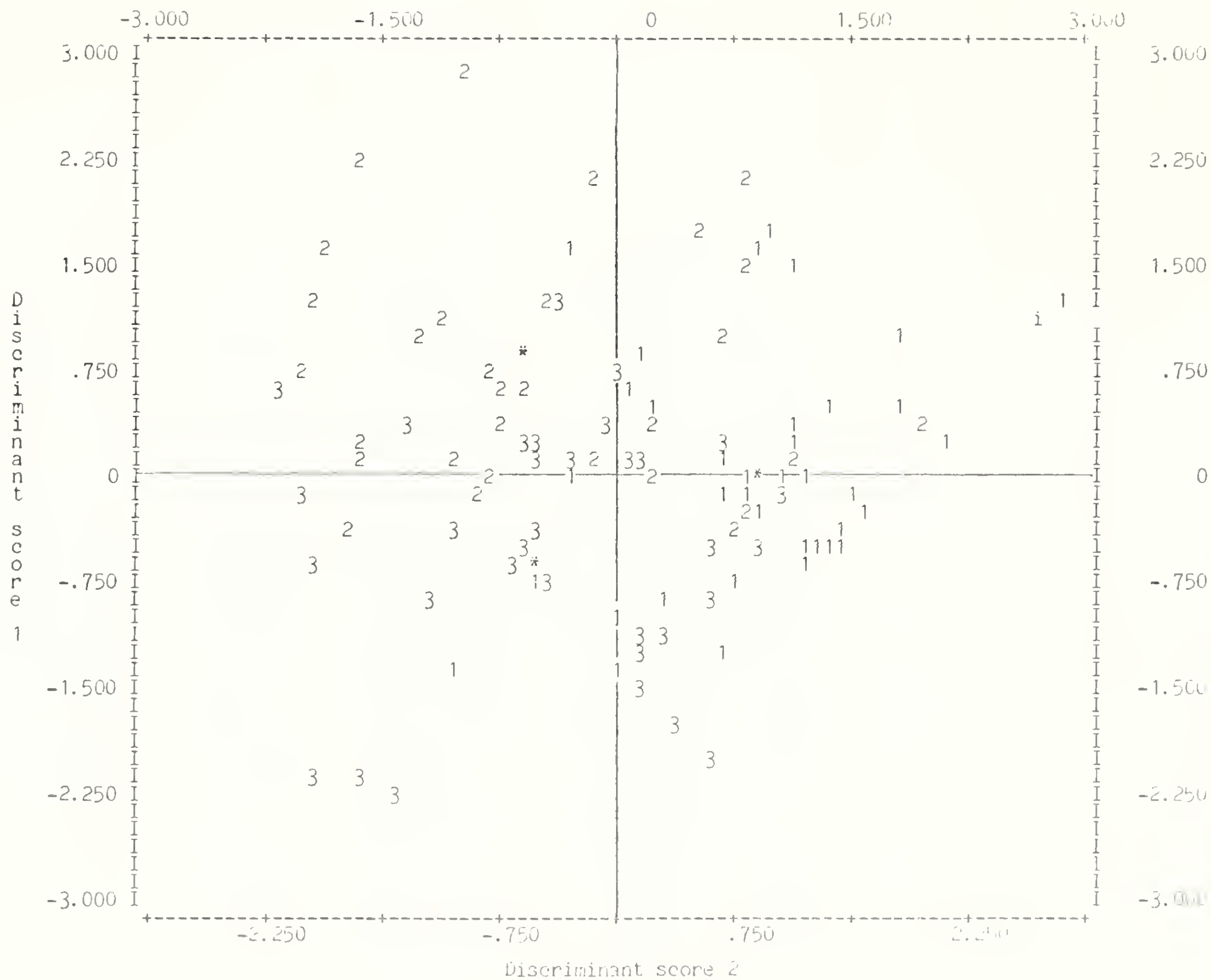

Figure 3.--Plot of discriminant scores and group centroids (*): otype 1.

present coyote control efforts, both corrective control and managerial prevention, have helped retard the increase of sheep losses to coyotes. However, ranchers with high losses and high control expenditures in one year will likely face the same expenditures and coyote threats the following year.

The large amount of unexplained variation in sheep and lamb losses can be attributed to one or more of the following possibilities:

1. Predation of sheep and lambs by coyotes may frequently be a random event; that is, high variation is normal.

2. Many producers do not keep complete records of sheep and lamb losses, and sometimes the cause of death is impossible to obtain.

3. The proxy for coyote numbers--the predator abundance indices gathered by the U.S. Fish and Wildlife Service (4)--may not reflect relative coyote population in areas where sheep are located. In most cases, the predator abundance survey lines were not located on the sheep ranches; in some cases, they were a considerable distance from the ranches.

4. Due to short-term leads and lags that actually occur between the time when losses are discovered and when effective controls are applied, correlations are lower than if the data had covered a longer period.

5. Variables other than the ones measured in this study may be important keys to predicting and explaining sheep and lamb losses to coyotes.

Many of the above inadequacies in the data base could be corrected or reduced by well-designed but highly expensive research designed to gather closely coordinated data on important variables (see (1), p. 33). Until this is done, the statistical definition of the impact of coyote control on predation losses will remain quite variable.

REFERENCES

1. Gee, C. Kerry, Richard S. Magleby, Warren R. Bailey, Russell L. Gum, and Louise M. Arthur, "Sheep and Lamb Losses to Predators and Other Causes in the Western United States," Agricultural Economics Report No. 369, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, 1977.

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4. U.S. Department of the Interior, Indices of Predator Abundance in the Western United States. Denver, Colorado: Bureau of Sport Fisheries and Wildlife, Denver Wildlife Research Center, 1975.

RELATED PUBLICATIONS

This is one of several recent reports on the sheep industry in the Western United States and the sheep-coyote issue. Copies of these reports are available from Publications, Room 0054-S, Economics, Statistics, and Cooperatives Service, U.S. Dept. of Agriculture, Washington, D.C. 20250.

"Characteristics of Sheep Production in the Western United States"
by C. Kerry Gee and Richard S. Magleby
Agricultural Economics Report No. 345.

About 80 percent of the sheep in the United States are raised in the West, where extensive private and public ranges provide the bulk of the feed. Only about 41 percent of the West's sheep producers have commercial scale operations of 50 head or more sheep, but they own nearly 93 percent of the region's sheep. About one-third of these commerical producers have specialized in sheep, while two-thirds have diversified livestock operations. More than two-thirds operate as sole proprietors, while the rest have formed partnerships and family corporations. Many have substantial equity positions which indicate past profitability. About one-fifth will likely be retiring in the next 10 years, which could result in many operations going out of sheep production. About half of the feed requirement for commercial sheep comes from private range, while public range supplies one-fifth. Over half of th commerical sheep are grazed under the care of herders, usually on open (unfenced) range. Most lambing occurs in late winter and early spring. More commerical producers practice shed lambing than range lambing, but the number of sheep involved is less. The principal marketing problem is the few number of buyers bidding on lambs.

"Sheep and Lamb Losses to Predators and Other Causes in the Western United States"
by C. Kerry Gee, Richard Magleby, Warren R. Bailey, Russell L. Gum, and Louise M. Arthur
Agricultural Economic Report No. 369

Predators, principally coyotes, are the major cause of lamb and sheep losses in the Western United States, according to 9,000 farmers and ranchers surveyed in 1974. Rates of loss to coyotes varied considerably among farmers and ranchers; while many had no or minor predation problems, others reported very high losses. Overall, in the Western United States losses attributed to coyotes in 1974 numbered 728,000 lambs (more than 8 percent of all lambs born) and 229,000 adult sheep (more than 2 percent of inventory), representing a third of the total lamb deaths to all causes and a fourth of the adult sheep deaths. These losses cost U.S. sheep producers some $27 million in lost returns in 1974, while consumers lost $10 million in benefits because of higher prices for lamb and reduced quantities available.

"Enterprise Budgets for Western Commerical Sheep Businesses, 1974"
by C. Kerry Gee
ERS 659

Sheep enterprise budgets for 1974 are presented for major producing areas of the 17 Western States. Summaries of production, costs, returns, and operating practices are given for enterprises of various sizes and with different management systems. Most sheep businesses did not have sufficient sales in 1974 to cover all expenses, and about 35 percent are unable to pay cash costs. Businesses in Texas-New Mexico realized the greatest return to invested capital. Small farm flocks in the wheat-corn areas of the Northern Plains States are least profitable.

"Factors in the Decline of Sheep Production in the Western United States"
by C. Kerry Gee, Darwin B. Nielsen, Delwin H. Stevens, and Richard S. Magleby
Agricultural Economic Report No. 377

Former sheep producers in Colorado, Texas, Utah, and Wyoming are surveyed to determine why they had discontinued sheep production. From

40 to 60 percent were found to have continued in some form of agricultural business, usually involving cattle. The others had retired or taken off-farm employment. Generally, the former sheep producers had smaller scale operations, more equity in the business, higher predation losses, lower earnings, and were older than producers continuing in the sheep business. Factors which they rated of greatest importance in their decisions to discontinue sheep production arehigh predation losses, low lamb and wool prices, shortage of good hired labor, and their own age.

"Coyote Control: A Simulation for the Evaluation of Alternative Strategies"
by Russell L. Gum, Louise M. Arthur, and Richard S. Magleby
Agricultural Economic Report No. (in press).

Present and alternative strategies for coyote control in the Western United States are evaluated using a computerized simulation model, which predicts the economic and socio-environmental impacts of each. Increasing expenditures from the 1974 level of $7 million to $20 million on the same mix of controls is predicted to result in a gradual decrease in lamb losses and an increase in net economic benefits. Socio-environmental benefits did not change significantly. Beyond the $20 million level of expenditures, net economic benefits are predicted to decline slightly and socio-environmental benefits decline rapidly. At expenditures below 1974 levels, both economic and socio-environmental benefits decline substantially. Changes in mixes of control methods are discovered which permit both economic and socio-environmental benefits to increase. These alternatives include increased use of the M-44 and aerial gunning and decreased use of traps.